PROCESS FOR THERMALLY TREATING LIGHT ALLOY CASTING

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

The present invention relates to a process for thermally treating a light alloy casting.

DESCRIPTION OF THE RELATED ART

To produce a light alloy casting, a solution heat treatment is conventionally employed for converting the light alloy casting into a homogeneous solid solution after the casting.

However, in the solution heat treatment, the quenching is carried out under atmospheric pressure after the heating, and hence there is a possibility that a gas (mainly hydrogen) exceeding a solid solution limit contained in the casting in the casting process, expands during the quenching, resulting in an increase in a porosity of the light alloy casting. There is also a possibility that the gas is transferred to a surface of the casting, generating blisters on the surface. These situations hinder an enhancement in toughness of the light alloy casting.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a thermal treating process, wherein an increase in porosity of the light alloy casting is inhibited, and the generation of blisters on the surface of the light alloy casting is prevented, whereby the toughness of the light alloy casting can be enhanced.

To achieve the above object, according a first feature of

the present invention, there is provided a process for thermally treating a light alloy casting, comprising: a step of heating a light alloy casting up to a solid solution range and maintaining it at such heating temperature T; and a step of quenching the light alloy casting through a cooling medium while pressurizing it.

The above-mentioned heating and quenching can provide an effect similar to that in the usual solution heat treatment, namely, an effect enabling the light alloy casting to be converted into a homogeneous solid solution. In addition, since the light alloy casting is quenched through the cooling medium while being pressurized, the expansion of the gas contained in the casting in the process of casting is suppressed, and the transfer of the gas to the surface of the casting is inhibited, whereby the generation of blisters on the surface can be prevented. Further, the cooling medium under pressure can be brought into close contact with the entire surface of the light alloy casting, whereby the cooling speed can be increased.

Therefore, this thermal treating process can produce a light alloy casting having a high toughness.

According to a second feature of the present invention, in addition to the first feature, the heating temperature T is set at $T > T_S$, wherein T_S represents a solidus-line temperature for a light alloy forming the light alloy casting. With this feature, it is possible to provide a thermal treating process by which a light alloy casting having a further enhanced roughness can be produced by employing the above-described means.

An applied pressure P in the process of quenching is suitable

to be in a range of 200 bar ≤ P ≤ 2,000 bar. If P < 200 bar, an effect of the pressurization is not provided. On the other hand, if P > 2,000 bar, the effect of the pressurization is not significant for an increment in pressure. However, the applied pressure P is more effective at a higher value in the above-described range (200 bar ≤ P ≤ 2,000 bar).

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Table 1 shows compositions of two types of aluminum alloys used for forming aluminum alloy castings as castings of light alloys, i.e., A356 alloy and ADC3 alloy (JIS), and Table 2 shows solidus-line temperatures T_S and liquidus-line temperatures T_L of the alloys.

Table 1

Al alloy	Chemical constituents (% by weight)							
	Si	Cu	Mg	Mn	Fe	Ti	Zn	Al
A356	7.43	0.04	0.43	0.03	0.16	0.36	0.02	Balance
ADC3	9.7	0.3	0.55	0.2	1.1	–	0.1	Balance

Table 2

Al alloy	Solidus-line temperature T_S	Liquidus-line temperature T_L
A356	555°C	610°C
ADC3	560°C	590°C

(Embodiment 1)

(1) A plurality of aluminum alloy castings I were formed by

utilizing a gravitational sand-die-casting process using an A356 alloy, and a plurality of aluminum alloy castings II were formed by utilizing a vacuum-die-casting process using an ADC3 alloy.

(2) A content of a gas in each of the aluminum alloy castings I and II was measured.

(3) Each of the aluminum alloy castings I and II was subjected to a thermal treatment which will be described below. Each of the aluminum alloy castings I and II was heated up to a solid-solution range (a range of temperature where the casting can exist as a homogeneous solid solution) under atmospheric pressure, and maintained at such heating temperature T. Then, each of the aluminum alloy castings I and II was quenched through a cooling medium under the atmospheric pressure or while being pressurized. Water was used as the cooling medium. In this case, each of the heating temperatures T was set in a range of $T \leq T_S$ (wherein T_S is a solidus-line temperature of the aluminum alloy forming each of the aluminum alloy castings I and II).

(4) Each of the aluminum alloy castings I and II was subjected to an artificial aging treatment at 160°C for 6 hours.

(5) A specific gravity of each of the aluminum alloy castings I and II was measured, and defined as an apparent specific gravity. A specific gravity of each of extrusion compounds comprising the A345 alloy and the ADC3 alloy was also measured, and defined as a true specific gravity. A porosity (%) was determined according to an equation: porosity = {(true specific gravity - apparent specific gravity)/true specific gravity} x 100.

(6) No.3 test pieces were fabricated from each of the aluminum alloy castings I and II in order to carry out a Charpy impact test where a Charpy impact value for each of the test pieces was measured.

Table 3 shows thermal treating conditions for the aluminum alloy castings I(1), I(2), II(1) and II(2).

Table 3

Al alloy casting		Thermal treatment				
		Heating process			Quenching process	
		Temperature (°C)	Pressure	Time (Hr)	Pressure (bar)	Time (min)
I	(1)	530	Atmospheric pressure	3	Atmospheric pressure	0.2
	(2)				1,000	30.0
II	(1)	530	Atmospheric pressure	3	Atmospheric pressure	0.2
	(2)				1,200	30.0

T_S for Al alloy casting I : 555°C

T_S for Al alloy casting II : 560°C

The reason why the time for the quenching process for the aluminum alloy castings I(2) and II(2) is longer that that for the aluminum alloy castings I(1) and II(1) in Table 3, is that a longer time is required for raising the pressure.

Table 4 shows the content of gas, the pressure in the quenching process, the apparent specific gravity, the true specific gravity, the porosity and the Charpy impact value for each of the aluminum alloy casting I(1), etc.

Table 4

Al alloy casting		Content of gas (cc/100g)	Pressure in quenching process (bar)	Apparent specific gravity	True specific gravity	Porosity (%)	Charpy impact value (J/cm^2)
I	(1)	0.7	Atmospheric pressure	2.670	2.685	0.56	9.5
	(2)		1,000	2.670		0.56	15.8
II	(1)	3.0	Atmospheric pressure	1.688	2.687	37.18	1.4
	(2)		1,200	2.681		0.22	12.4

The aluminum alloy castings I(1) and I(2) having the smaller content of gas were compared with each other. As a result, no blister was observed on surfaces of the aluminum alloy castings, and it was found that their apparent specific gravities were substantially the same and their porosities were substantially the same, but the aluminum alloy casting I(2) had the Charpy impact value larger than that of the aluminum alloy casting I(1). It is considered that this is because the cooling medium under pressure was brought into close contact with the entire surface of the aluminum alloy casting I(2), whereby the cooling speed was increased.

The aluminum alloy castings II(1) and II(2) having the larger content of gas were compared with each other. As a result, a plurality of blisters were observed on the surface of the aluminum alloy casting II(1) which was not pressurized in the quenching process, but the generation of blisters was not observed on the surface of the aluminum alloy casting II(2) which was pressurized in the quenching process. In the aluminum alloy

casting II(2), its apparent specific gravity was increased, and its porosity was remarkably lower than that of the aluminum alloy casting II(1), whereby a remarkable increase in Charpy impact value was observed.

(Embodiment 2)

(1) A plurality of aluminum alloy castings IV were formed by utilizing a gravitational sand-die-casting process using an A356 alloy, and a plurality of aluminum alloy castings V were formed by utilizing a vacuum-die-casting process using an ADC3 alloy.

(2) A content of a gas in each of the aluminum alloy castings IV and V was measured.

(3) Each of the aluminum alloy castings VI and V was subjected to a thermal treatment which will be described below. Each of the aluminum alloy castings IV and V was heated up to a solid-solution range, and maintained at such heating temperature T. Then, each of the aluminum alloy castings IV and V was quenched through a cooling medium, while being pressurized. Water was used as the cooling medium. In this case, each of the heating temperatures T was set in a range of $T > T_S$ (wherein T_S is a solidus-line temperature of the aluminum alloy forming each of the aluminum alloy castings IV and V). If the heating temperature T is set as described above, a portion of an eutectic (Al + Si) which is a low-melting-point precipitated crystal hindering the toughness as well as an intermetallic compound AlSiFe, can be molten.

(4) Each of the aluminum alloy castings IV and V was subjected

to an artificial aging treatment at 160°C for 6 hours.

(5) A specific gravity of each of the aluminum alloy castings IV and V was measured, and defined as an apparent specific gravity. A porosity (%) was determined using this apparent specific gravity, the above-described true specific gravity and the above-described equation.

(6) No.3 test pieces were fabricated from each of the aluminum alloy castings IV and V in order to carry out a Charpy impact test, and a Charpy impact value for each of the test pieces was measured.

Table 5 shows thermal treating conditions for the aluminum alloy castings IV(1), IV(2), V(1) and V(2).

Table 5

<table>
<tr><th colspan="2" rowspan="3">Al alloy casting</th><th colspan="5">Thermal treatment</th></tr>
<tr><th colspan="3">Heating process</th><th colspan="2">Quenching process</th></tr>
<tr><th>Temperature (°C)</th><th>Pressure</th><th>Time (Hr)</th><th>Pressure (bar)</th><th>Time (min)</th></tr>
<tr><td rowspan="2">IV</td><td>(1)</td><td rowspan="2">567</td><td rowspan="2">Atmospheric pressure</td><td rowspan="2">3</td><td>Atmospheric pressure</td><td>0.2</td></tr>
<tr><td>(2)</td><td>1,000</td><td>30.0</td></tr>
<tr><td rowspan="2">V</td><td>(1)</td><td rowspan="2">567</td><td rowspan="2">Atmospheric pressure</td><td rowspan="2">3</td><td>Atmospheric pressure</td><td>0.2</td></tr>
<tr><td>(2)</td><td>1,200</td><td>30.0</td></tr>
</table>

T_S for Al alloy casting IV: 555°C

T_S for Al alloy casting V: 560°C

The reason why the time for the quenching process for the aluminum alloy castings IV(2) and V(2) is longer in Table 5, is that a longer time is required for raising the pressure.

Table 6 shows the content of gas, the pressure in the quenching process, the apparent specific gravity, the true

specific gravity, the porosity and the Charpy impact value for each of the aluminum alloy casting IV(1), etc.

Table 6

Al alloy casting		Content of gas (cc/100g)	Pressure in Quenching process	Apparent specific gravity	True specific gravity	Porosity (%)	Charpy impact value (J/cm^2)
IV	(1)	0.7	Atmospheric pressure	1.500	2.685	44.13	2.3
	(2)		1,000	2.672		0.48	16.4
V	(1)	3.0	Atmospheric pressure	1.701	2.687	36.70	1.4
	(2)		1,200	2.674		0.48	14.6

The aluminum alloy castings IV(1) and IV(2) having the smaller content of gas were compared with each other. As a result, in the aluminum alloy casting IV(1), pores created due to the melting of a portion of an eutectic (Al + Si) in the heating process were expanded in the quenching process, so that the apparent specific gravity was decreased, while the porosity was increased, and consequently, the Charpy impact value was extremely low. In the aluminum alloy casting IV(2), pores are contracted by the pressurization in the quenching process to increase the apparent specific gravity, while decreasing the porosity. Therefore, the Charpy impact value was remarkably high. This applies to the aluminum alloy castings V(1) and V(2).

Due to the rise of the heating temperature T in the heating process, the aluminum alloy castings IV (2) has a Charpy impact value higher than that of the aluminum alloy casting I(2) shown in Table 4 and obtained from the thermal treatment under the same

thermal treatment conditions expect for the heating temperature T. This applies to the aluminum alloy castings V(2) and II(2).

Also in the heating process, it can be expected that the characteristics of the aluminum alloy casting can be improved by applying a pressure to the aluminum alloy casting. In this case, if the quenching is carried out under the application of the pressure, a time for raising the pressure in the quenching process can be eliminated, and a time for the quenching process can be greatly shortened. This is effective for providing an enhancement in productivity of the aluminum alloy castings.

According to the first feature of the present invention, it is possible to provide a thermal treating process by which a light alloy casting having an excellent roughness can be produced by employing the above-described means.

According to the second feature of the present invention, it is possible to provide a thermal treating process by which a light alloy casting having a further enhanced roughness can be produced by employing the above-described means.